FOI – Swedish Defence Research Agency

Research for a safer and more secure world

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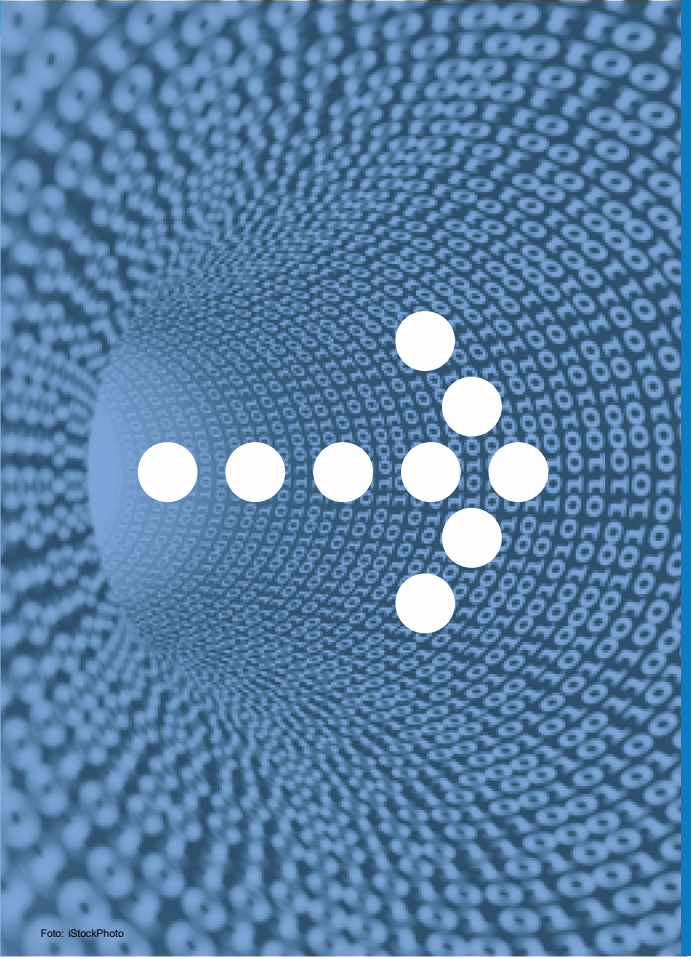

GNSS threats – Jamming and spoofing Robust

Fredrik Marsten Eklöf
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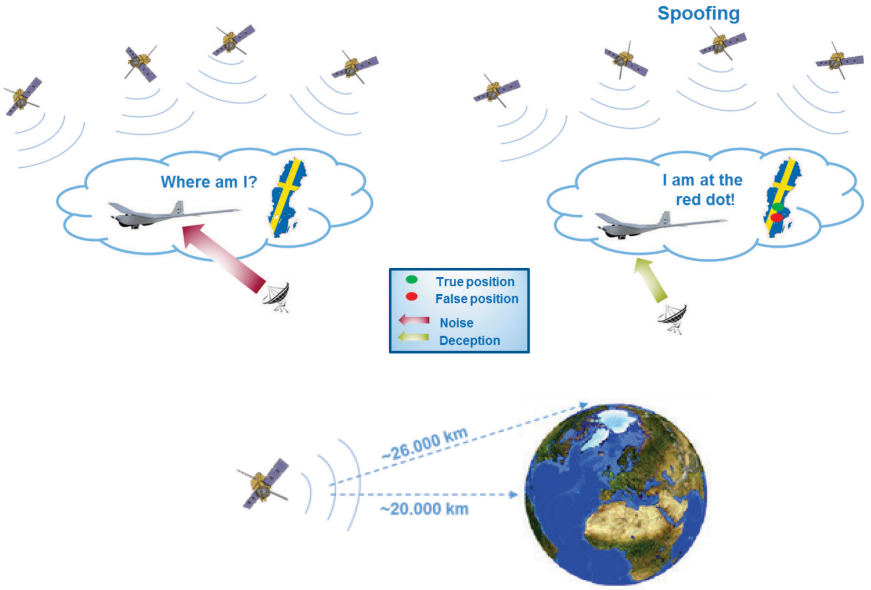
Vulnerability GNSS

- Interference (unintentional)
- Jamming – signal denial
  - GNSS is vulnerable/sensitive to jamming (RF) due to the low received signal power
  - A low power jammer can achieve high relative power levels compared to the GNSS-signals
- Spoofing – Deception
  - The purpose with spoofing is deceive one or several GNSS-receiver and the system
  - Generate erroneous PNT solution



Main reason for the sensitivity towards jamming is the large distance to the satellites

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Google search: GPS/GNSS Jammers

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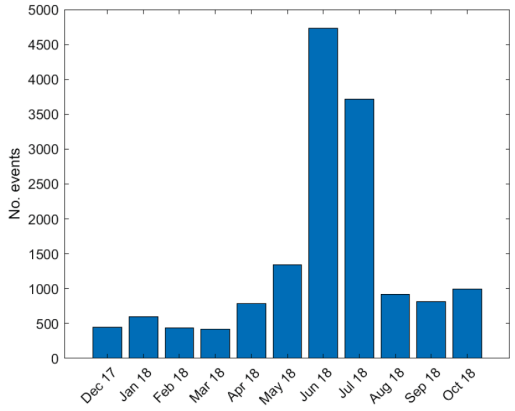
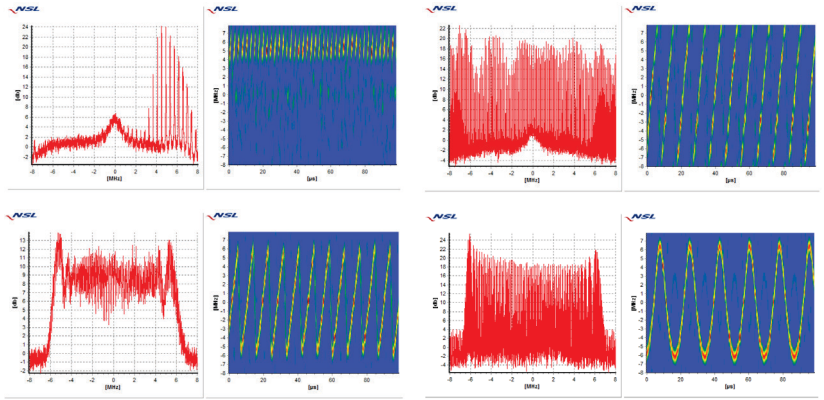
Interference



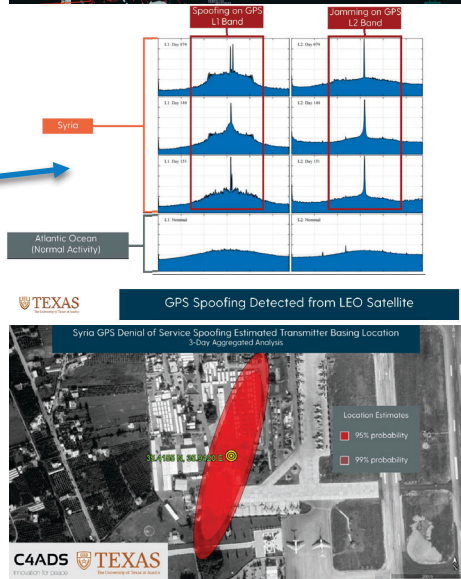
- Unintentional interference and jamming
- STRIKE3 (EU funded project)
  - 500 000 events detected
  - 70 000 estimated to be intentional jamming (“Personal / Privacy / Protection Device” - PPD)

    >15 000 denied GNSS
- http://gnss-strike3.eu/



Jamming

- Jamming (by state actors) experienced during military exercises
  - e.g. ZAPAD17, Trident Juncture, …
  - Denies GNSS for civilian airliners, ships, etc
- Also commonly experienced close to conflict areas
  - Syria (Russian Khmeimim Air Base)
  - Libya
  - Korean Peninsula
  - Persian Gulf
  - …



Internet GPS-jammer

Custom declaration:

- Declared as car adapter to avoid customs
- Contains no packing material of Chinese wood

SHENZHEN TAYX TECHNOLOGY DEVELOPMENT CO., LTD

5B1, 2ND BUILDING, CITY OF DESIGN, ZHENHUA WEST RD, SHENZHEN, CHINA TEL.: 0086-755-8883 6239

COMMERCIAL INVOICE

SHIPPING ADDRESS:

To:

Address:

Phone:

Date : APR 10, 2013
Invoice No.: ERUJAM1734
From: Michael
Page: 1

Description of Goods	Quantity/PC	Unit Price/USD	Amount/USD
CAR ADAPTOR (No Battery Inside)	2	15	30
		Total :	**USD 30**

TOTAL THIRTY USD ONLY.

REMARKS:

TOTAL WEIGHT IS KG. COURIER IS DHL HK.

COUNTRY OF ORIGIN IS CHINA.

WE HEREBY STATED THAT THE ABOVE EQUIPMENT CONTAINS NO SOLID WOOD PACKING MATERIALS FROM CHINA.

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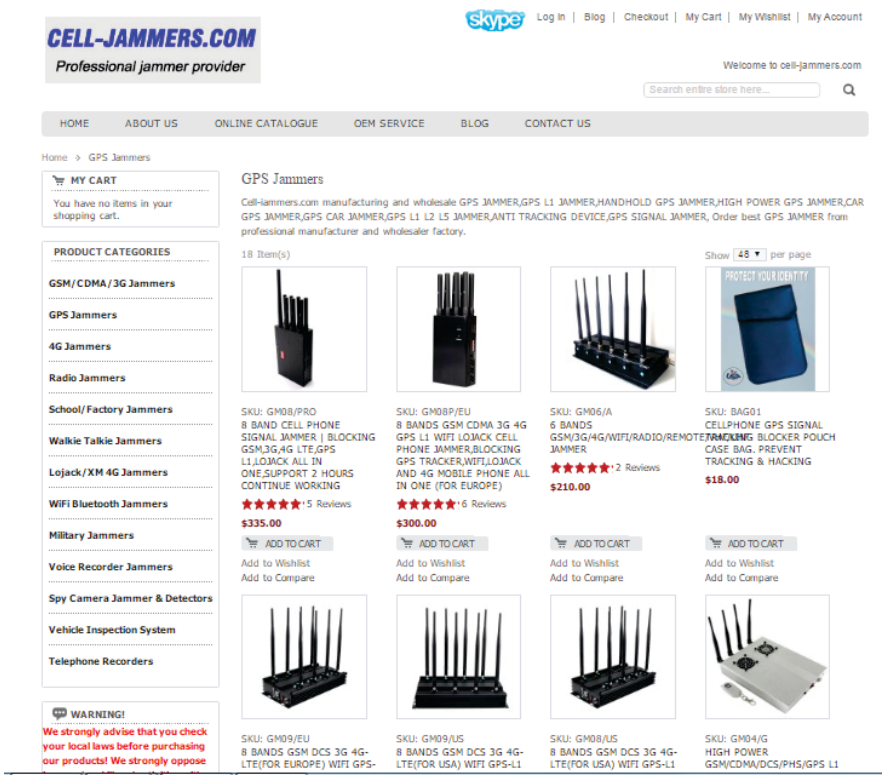
GNSS-jammers

- http://www.cell-jammers.com/gps-jammers
- http://www.alljammer.com/
- http://www.thesignaljammer.com/categories/GPS-Jammers/
- http://www.jammerfromchina.com/categories/GPS_Jammers/



Marketing of jammers - YouTube

- https://www.youtube.com/watch?v=JCHcq2Fzsh8
- https://www.youtube.com/watch?v=-6hI5aTV2O8
- https://www.youtube.com/watch?v=Sj6KS6zoiJQ
- http://www.youtube.com/watch?v=uHm8eXyPaNU
- http://www.youtube.com/watch?v=PtHU9pXV0XQ
- http://www.youtube.com/watch?v=-2ozZfKoD4o&list=PL1A88EBEE4CCD08FE
- http://www.youtube.com/watch?v=_VDrH1By0Ss&feature=endscreen&NR=1
- http://www.youtube.com/watch?v=QKZI06cgi8M

Example: Swedish incident

- Nazist ska ha kartlagt journalister – döms för grovt vapenbrott
  – DN 2018-09-05
- ”48-åriga xx är aktiv nazist och medlem i Nordiska motståndsrörelsen. Han ska ha förvarat ett stort antal vapen och vapendelar samt kommunikationsutrustning och ***störsändare.***”

Sweden:

- Illegal to use and own jamming equipment
- Number of persons has been convicted
- Fine from 25 000 skr.

- Swedish police inform public regarding jamming equipment
- Specific for remote locking of cars

polisen.se

Polisen varnar för störsändare

Låste du bilen?

Polisen

En ny metod för att stjäla från bilar är att använda en så kallad störsändare. Det är en elektronisk apparat som blockerar/ stör ut den signal som bilnyckeln sänder till bilen när du trycker för att låsa och eventuellt också larma den.

- Kontrollera därför att din bil är låst när du lämnar den. Annars är det fritt fram för gärningsmannen att öppna den olåsta och olarmade bilen och tömma den på innehåll.
- En störningssändare kan variera i utseende och storlek. Den ser vanligen ut ungefär som en handhållen kommunikationsradio med en eller flera antenner.
- Om du inte kan låsa din bil med nyckel när du parkerar på en större p-plats, och det inte beror på dåliga batterier, så ber vi dig att ringa polisen och vara vaksam på personer i den närmsta omgivningen.

Försäkra dig om att bilen är låst när du lämnar den. Om du vill anmäla ett brott eller tipsa polisen, ring 114 14. I akut läge (pågående brott) ring 112.

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Example: Norwegian incident

- **«Jammet» GPS-signaler – luftambulanse på vei til Røyken-ulykke rammet**
- Vid en svår trafikolycka där ambulanshelikopter fick avbryta flygning kort efter start då GPS-tappades och flera andra system påverkades
  - ”vanliga” ambulanser fick rycka ut
- Nasjonal kommunikasjonsmyndighet (Nkom) gjorde tillsyn i området och påträffade två lastbilar med GPS-störsändare
  - Från postnord…..
- Incidenter/påverkan har inträffat tidigare (10-15 ggr)

Lastebilsjåfører blokkerte GPS-signalene til ambulansehelikopter. Det skjer stadig oftere.

Nasjonal kommunikasjonsmyndighet (Nkom) har tre hypoteser som kan forklare hvorfor lastebilsjåfører kjører rundt med GPS-jammere.

Hans O. Torgersen
Per Byhring (multimedia)

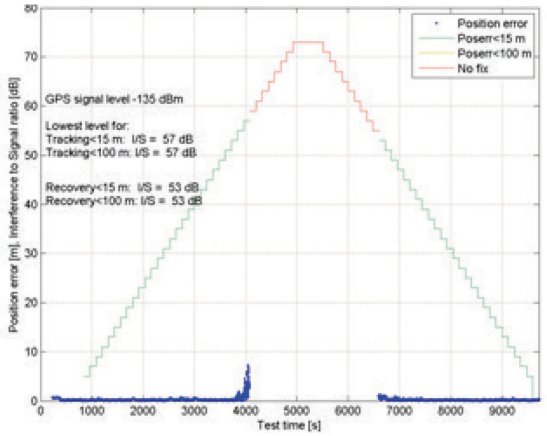
Publisert: 25.mar.2019 21:34
Oppdatert: 27.mar.2019 11:13

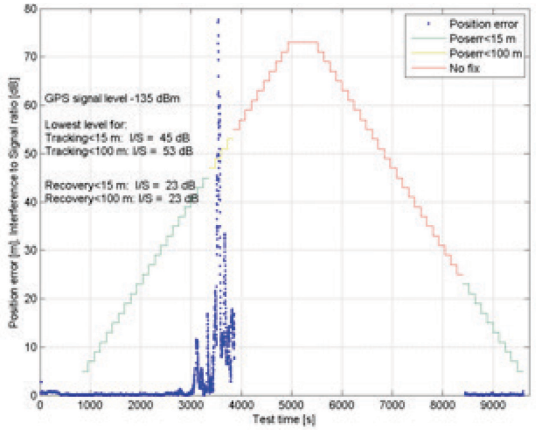
«Jammet» GPS-signaler – luftambulanse på vei til Røyken-ulykke rammet

FASTKLEMT: Mannen i stasjonsvognen ble sittende fastklemt etter ulykken. Han ble senere fraktet til sykehus med luftambulansen. Foto: Edgar Dehli

Effect of jamming on GNSS

- Jammer signal blocks the GNSS-signal
- How a GPS-receiver is affected depends on the receiver implementation and jamming waveform
- Usually accuracy is degraded before the receiver can not determine a PNT solution





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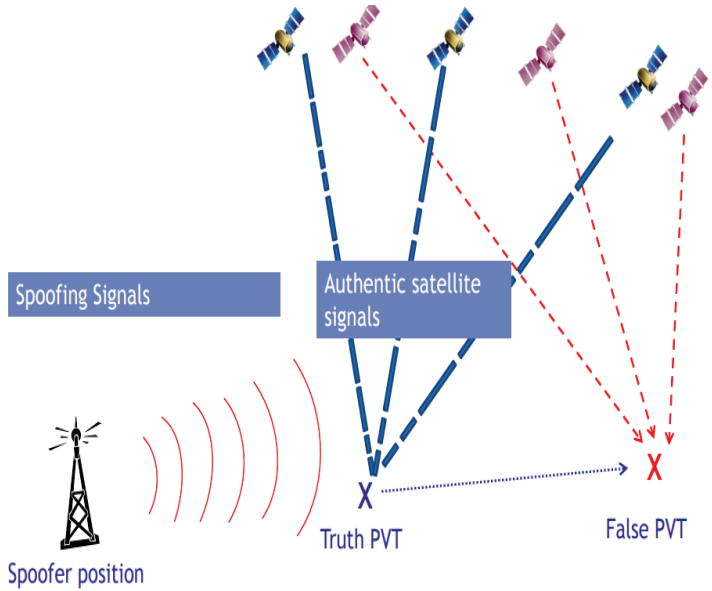
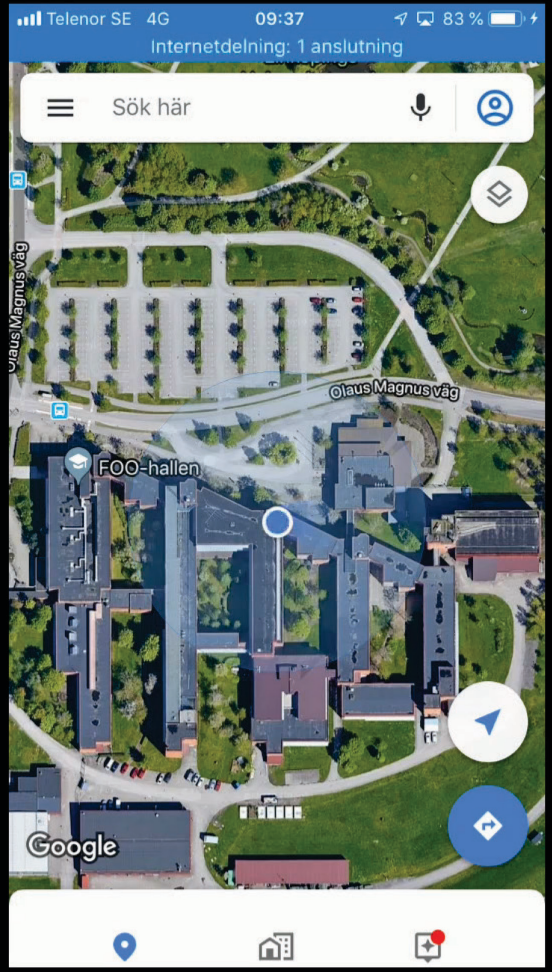
GNSS deception/Spoofing

- The purpose with spoofing is to force one or several GNSS-receivers to present an erroneous position and/or time
- Possible to locally generate GPS/GNSS signals
  - Public documents describe the GNSS-signals
  - A standard GNSS-receiver will not detect or exclude the false/spoofing signal
- A spoofing attack can be performed in in several different ways and with different type of equipment
  - Complete capability to control the receivers PNT-solution to introducing false/erroneous PNT – solution
- Earlier the spoofing threat was considered to be low but today there is a significant development of methods, techniques and hardware for spoofing
- The Next Big Threat to National Security is ‘Spoofing’
  - director of the CIA. Mike Pompeo before the Senate Intelligence Committee on January 12, 2017





GNSS deception

- Deception equipment used to be an expensive, exclusive resource; the hardware is now inexpensive (e.g. HackRF One SDR)
- Software easily available on the internet
- The software is easy to use and generates correct GPS-signals that are accepted and used by a GPS-receiver
- The software can be developed to include additional GNSS-signals

1 MSEK

200 SEK

GPS-SDR-SIM

GPS-SDR-SIM generates GPS baseband signal data streams, which can be converted to RF using software-defined radio (SDR) platforms, such as bladeRF, HackRF, and USRP.

Windows build instructions

1. Start Visual Studio.
2. Create an empty project for a console application.
3. On the Solution Explorer at right, add "gpssim.c" and "getopt.c" to the Souce Files folder.
4. Select "Release" in Solution Configurations drop-down list.
5. Build the solution.

Building with GCC

```
$ gcc gpssim.c -lm -O3 -o gps-sdr-sim
```

Generating the GPS signal file

A user-defined trajectory can be specified in either a CSV file, which contains the Earth-centered Earth-fixed (ECEF) user positions, or an NMEA GGA stream. The sampling rate of the user motion has to be 10Hz. The user is also able to assign a static location directly through the command line.

https://nrkbeta.no/2017/09/18/gps-freaking-out-maybe-youre-too-close-to-putin/

https://github.com/osqzss/gps-sdr-sim

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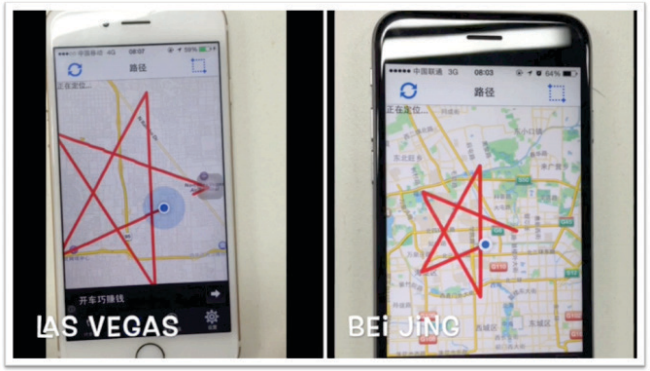
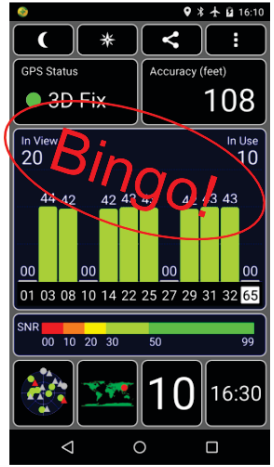
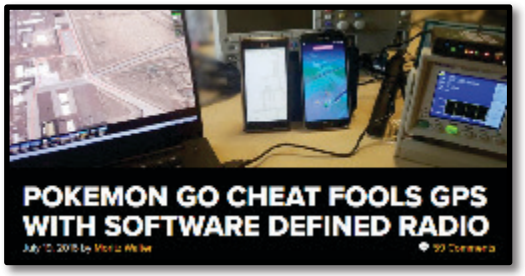
Spoofing – SDR (software defined Radio)

- The presentation describes in detail how a GNSS SDR spoofer can be developed
- The problems are described and solutions are presented
- For the developed SDR spoofer the scenario can be generated with input from Google Maps
- Demonstrates that the SDR spoofer can be used against GNSS-receivers in different applications
  - Mobile phones (NEXUS 5, Iphone6, Samsung Note 3)
  - UAV (DJI drone)
  - Vehicle navigationsystems







https://media.defcon.org/DEF%20CON%2023/DEF%20CON%2023%20presentations/DEFCON-23-Lin-Huang-Qing-Yang-GPS-Spoofing.pdf

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Links: spoofing

- GPS Spoofing w/ BladeRF - Software Defined Radio Series #23
  - https://www.youtube.com/watch?v=VAmbWwAPZZo
- Real-time GPS positioning with bladeRF
  - https://www.youtube.com/watch?v=uf2vatqek_o
- Generate a GPS signal and send it with HACKRF One, to deceive GPS receivers
  - https://www.youtube.com/watch?v=nUrw9aHrKTY
- Legal GNSS Spoofing and its Effects on Autonomous Vehicles
  - https://www.youtube.com/watch?v=gxwkovHh3Ac
- Simulation for GPS/GNSS Jamming and Spoofing
  - https://www.youtube.com/watch?v=8aI-Ibg4PGM

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Spoofing incidents: Spoofing in the Black Sea

- Between June 22-24, a number of ships in the Black Sea reported erroneous GPS-positions
  - The reported positions were located at an airport
- This was most likely a real spoofing attack
  - Several ships were affected at the same time and area
  - ships reported that their positions would periodically “jump” from the true location to the incorrect location.
- The location of the spoofer has been estimated to Russian territory, close to the Black Sea coast.

Spoofing in the Black Sea: What really happened?
GPS world, October 11, 2017 - By Michael Jones

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Spoofing

- GNSS spoofing (by state actors)
  - Over 1 300 spoofing events in waters around Russia found by analyzing maritime AIS data
  - Numerous reports from Moscow (around Kremlin)
  - Motivation - protection of president Putin, critical facilities, etc

Spoofing

- GNSS spoofing attack against an autonomous car
- The autonomous car deviated from the path with 10 meters and drove of the road

Simulerad gps-attack fick testbilen att köra av vägen

2019-05-03 06:55 Av: John Edgren 11 kommentarer

Ett forskningsinstitut i Texas har utvecklat ett test som visar hur autonoma fordon påverkas när gps-signalen manipuleras. Institutets bil avvek tio meter från sin kurs, och körde av vägen.

Recommendations

- Civil community
  - Important that civilian actors prepare to meet the threat against GNSS from jamming *and spoofing*
  - Possible to achieve significantly higher robustness both on receiver and system level
  - Galileo Public Regulated Service (PRS)


Right, so where are we with GNSS?